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The Next Generation Control System of GANIL

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Abstract

The existing computer control system of GANIL is being renewed to fulfil the increasing requirements of the accelerator operation. This medium term major improvement is aiming at providing the physicists with a wider range of ion beams of higher quality under more flexible and reliable conditions.

This paper gives a short description of the new control system envisioned. It consists of a three layer distributed architecture federating a VAX6000-410/VMS host computer, a real time control system made up of a dual host VAX3800 and workstation based operator consoles, and at the frontend segment: VME and CAMAC processors running under the VAXELN operating system, and programmable logic controllers for local controls.

The basic issues with regard to architecture, human interface, information management, ... are discussed. Lastly, first implementations and operation results are presented.

I. INTRODUCTION

The GANIL laboratory has been operating since 1983 an accelerator complex consisting of three machines in cascade : a compact injector cyclotron and two fourfold separated sector cyclotrons (Fig. 1).

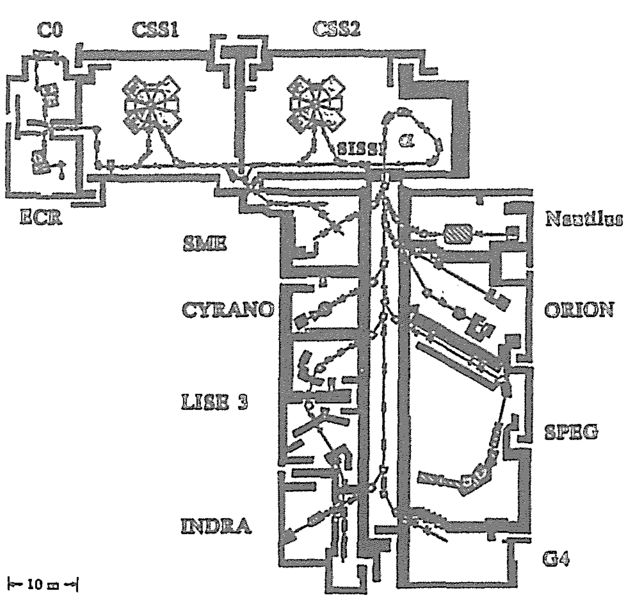

Figure 1. Accelerator and Experimental Areas

This facility provides the experimenters with fast heavy ion beams for fundamental research in the fields of nuclear physics, atomic physics and solid state physics, as well as for industrial applications.

Significant upgrades were carried out these last few years to augment the energy of heaviest ion beams and to increase their intensities by making use of new ECR source. Acceleration at GANIL henceforth encompasses ion species, from carbon to uranium, with beam energy ranging from up to 95 MeV per nucleon for the ions with masses up to 40 u to 24 MeV per nucleon for the heaviest ions.

The rejuvenation of the GANIL computer control system is under way, aiming at two main goals : 1/supersedes the present control system which is technologically outmoded and driven to its ultimate capabilities, 2/matches the performances of the emerging control system with the widening scope of the services in a large variety of domains (beam setting and tuning, surveillance, diagnostics, expertise,...) within an operator friendly environment.

This paper emphasizes the main topics to be considered when designing and implementing our next generation control system. In particular, stress is laid on using : 1/acknowleged industry or international open standard hardware and software products to achieve minimization of investment over the life of the system, 2/modular structures to make easier future expansions.

II. ACCELERATOR CONTROL SYSTEM

II.1. General Layout

The first generation control system adopted a centralized architecture built with a 16bit minicomputer (MITRA 625) which ruled over other kinds of processors devoted to local or ancillary tasks : 8bit (JCAM10/INTEL 8080) and 16bit (DIVA/MC68K) microprocessor CAMAC controllers, programmable logic controllers (APS30-12 and PB400). These processors are connected to the MITRA via two bit-serial 2.5 MHz CAMAC loops which bind up 40 crates with about 800 attached modules.

This tight coupling with the computer MITRA considering architecture and non portable software makes the control system vulnerable with regard to collapse, obsolescence and ageing of that computer.

In contrast, the GANIL control system to come is based on a distributed architecture. Intelligence is therefore handed over to local processors which are responsible for dedicated field operations. The chosen topology features three functional levels which intercommunicate by means of an Ethernet local area network (LAN) :

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1. The HOST level provides a general purpose and cosy environment for software programming, debugging, off-line calculations and displays, database management, and simulation. It is built around 1/ - a midrange DIGITAL EQUIPMENT computer, the VAX600-410, connected to video terminals through DECservers, 2/ - workstations VS3100-76 equipped with 19' high definition color screens for graphics oriented developments.

This level also realizes links with other facilities of the laboratory : compatible PC's and Mac serviced by a NOVELL server, CAD stations and the Physics acquisition Vax-cluster ; in addition, it provides connection to remote physics laboratories via wide area netwoks (WAN).

2. The REALTIME CONTROL level allows operators to control the accelerator by means of appropriate human interfaces. This level is based on a microVax3800, seven workstations VS3100 and X-terminals VT1300 to benefit from the enhanced graphic capabilities within the X11 standard multiwindowing environment. VAXELN controlled VME boards are used to drive the shaft knobs. Man-machine interaction will be emphasized in § II.4. The µVAX3800, which plays a key role in the real time control, is actually a dual host cluster equiped with redundant disks to achieve some kind of "failure tolerance ".

3. The EQUIPMENT level perfoms low level controls with different kinds of front end processors :

- CAMAC controllers (KSI3968 from KINETIC SYSTEMS) and VME controllers (VME300 from AEON, ...) running real-time applications under the VAXELN operating system. These controllers which are referred to as front end controllers (FEC) integrate the RTVAX300 chip, the CAMAC FEC replacing the present serial loop crate controllers.

- Programmable logic controllers (PLC) : S5-135U from SIEMENS, PB400 from TELEMECANIQUE/APRIL.

CAMAC and VME FEC, as well as the SIEMENS PLC are directly connected to the controls Ethernet LAN. Communication between VAX processors and SIEMENS PLC is achieved by DEC software packages : VSH1 which supports the application-presentation - session layers of the OSI/ISO standard and VOTS which provides services of the two next lower layers. The PB400 PLC are connected to the server node µVAX3800 by means of an asynchronous serial link that supports the master/slave JBUS communication protocol. The very first APS30-12 programmable controllers, which are devoid of LAN connexion capability, are phased out.

The general Ethernet LAN, is linked to the sensitive control Ethernet LAN via a bridge chosen for its filtering capability. Communication protocols which are currently DECnet, TCP/IP, LAT will comply with the OSI standard. Fig 2 displays the layout of the future control system.

II.2 Software considerations

Requirements

It is a matter of fact that software is taking a leading part in modern control system, as compared to hardware, with high added value caused by large human effort (many people involved over a long time to carry out).

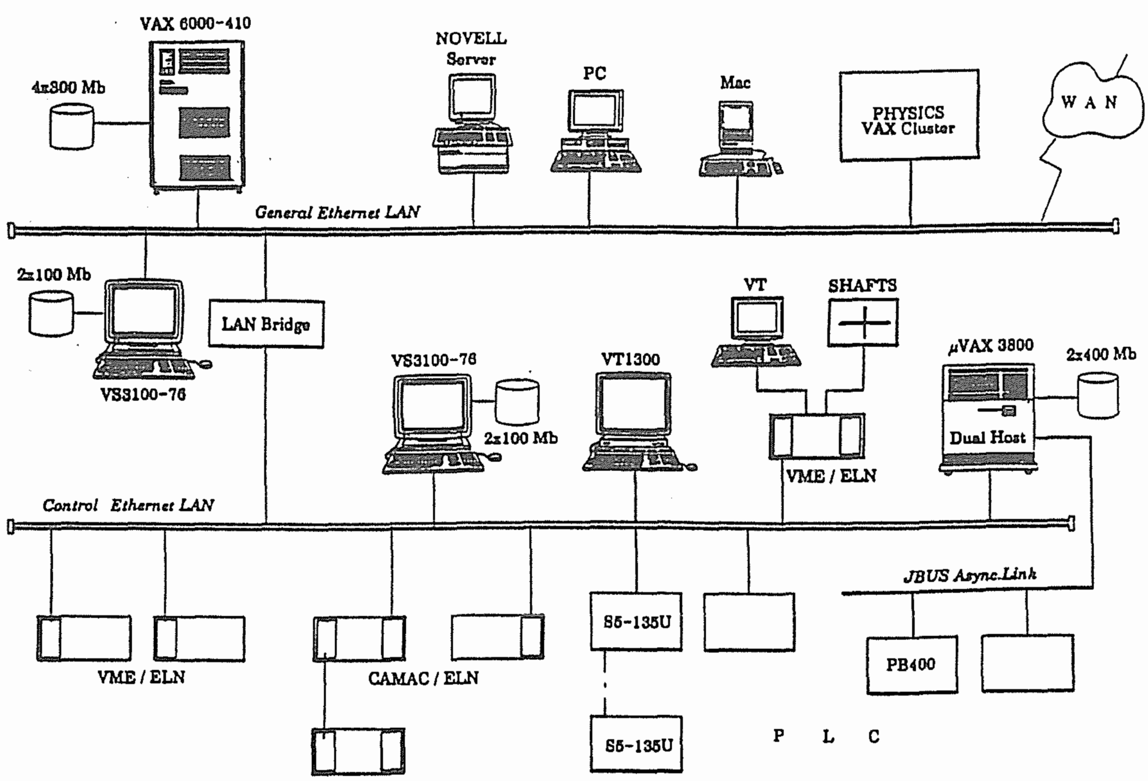

Figure 2. Schematic layout of the future Control System

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Our basic requirements are :

- Dependable software to achieve productivity taking into account modern tools and methods.
- Trustworthy and easy operation which implies ergonomics.
- Well guided maintenance.
- Durability. GANIL evolutions, as a physics laboratory may be stressing, unforeseen and of large amplitude. The control system should face such a situation in the smoothest possible fashion.

Choices

To meet our requirements, standardization is the key.

Operating systems : VMS for VAX processors and VAXELN for real time controls are adopted. VAX/VMS is an industry (de facto) standard widely used in physics laboratories, VAXELN is chosen as a mature and powerful product which is tailored for real time performances. It supports a host/target connection over DECnet within a full VAX/VMS compatible environment. Therefore, the host processor VAX6000-410 performs developments and debugs while the targets (CAMAC and VME FEC) execute real-time controls.

Languages : A multilanguage system is chosen with ADA, Fortran and C. These languages comply with AFNOR, ANSI and ISO standards. ADA is our major programming language, while assembly language is relinquished.

Industry softwares : In addition to the software packages devoted to the VMS environment, LAN communication and management, some important software packages are selected :

. the INGRES family from ASK/INGRES devoted to relational database management (more in §II.3)

. the IMAGIN family from SFERCA devoted to supervision (more in §II.4)

. Xwindows and MOTIF (X11R4).

Implementations

A basic software layer has to be designed to meet the specific control requirements of the GANIL accelerator. This so called GANICIEL layer is mainly transparent to the users and is built upon the industry softwares.

It makes widely use of the client-server model and takes into consideration the distributed architecture which allows the clients and the server to run on different processors located anywhere in the LAN.

The following emphasizes the distribution of the GANICIEL functions over the control system levels :

At real time control level

The µVAX3800 assumes the function of a global server that is fanned out into dedicated functional programs to handle remote incoming requests.

Important ones are :

- Initiation of appropriate functions (e.g. communication, tasking, ...) on boot or on resumption.
- Surveillance of networking operation and FEC execution.
- Alarm handling which deals with concentration, storage and display for operator decision, in instant mode or differed mode with customized presentation.
- Data base management

. SQL translation of request stemming from FEC

. Dispatch dedicated run time database to the proper processor

. Update in partial mode for some pieces of equipment or in global mode (e.g. changing acceleration conditions)

. Archiving (e.g. beam parameters, profiles, settings, operation logs,...) processing and presenting.

Workstations assum human operator interface :

- Xterminal management for operator choice (task and hook names).
- Process server to run processes selected by the Xterminal.
- Translation algorithm to change hook names into hardware addresses.
- Local presentation of alarms.
- Beam control processes with MOTIF widgets as operator interface.

At equipment level

Controls are handed over to CAMAC/VAXELN and VME/VAXELN front end controllers. GANICIEL functions provided by these FEC are displayed on Fig 3.

Real time processes achieved at this level are :

- Communication servers to receive all the requests from workstations or other crate controllers.
- Hook to reserve and refresh the values of hooked pieces of equipment.
- Surveillance to check whether a piece of equipment is off specified limits.
- Alarms to send message to the main alarm server running on µVAX3800.
- Handlers to control piece of equipment with drivers that only control the CAMAC.

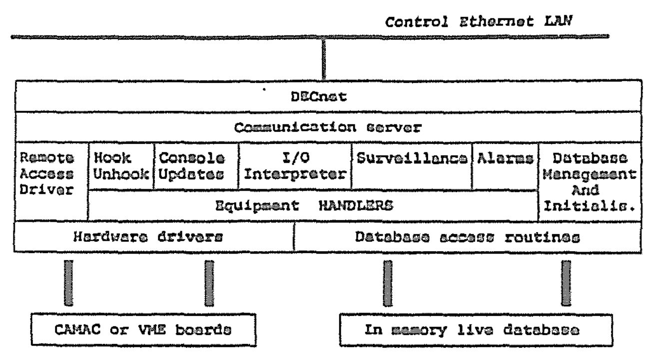

Figure 3. GANICIEL Functions on FEC

II. 3 Information management

Information management is of basic importance in a control system. Due to :

1. the various natures of information to manage :

- acceleration conditions, beam parameters (ion species, energies,...)
- realtime controls (node addresses, equipment identifications and characteristics, alarm messaging,...)
- operation logs
- reference characteristics of controlled parts (hardware installation and software)

2. the huge amount of controlled data (e.g. > 2500 pieces of equipment, beam parameters,..)

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3. the distributed topology of our control system architecture (data flow vs time, up - and downloading, ...), information management has to be carefully analyzed and designed to meet performances (access, integrity, speed,...) and avoid conflicts which may be fatal.

Database management system

A careful investigation has led us to adopt a relational database management system (RDBMS) to fulfil our needs regarding NON-realtime purposes. We finally chose the commercial INGRES RDBMS as having specifications which fulfil our requirements and feature the open aspects we are looking for. Main reasons are listed as followed :

- Hardware independency, which allows straight forward integration in the VAX/VMS environment.
- Comply with SQL standard.
- Encompasss a 4th generation language in windowing environment (W4GL).
- High integrity, homogeneity of the products (QBF, ABF, ...) with good ergonomy consideration.
- ADA interfacing.
- and last but not least, a quality support.

Realtime database

Realtime database is hosted in the μVAX3800. It is fragmented into dedicated live databases reflecting the hardware configuration of the frontend CAMAC or VME/VAXELN local controllers. At these lower level locations, live databases are eventually reformated into appropriate structures for easy access by equipment handlers and for fast response, and reduced for memory saving. These live databases actually include static information and dynamic data about the operation of the controlled pieces of equipment or subsystems, under the management of a DBserver. Downline loading of live database may be a critical concern to be mastered.

II.4 Human interface

Human interface at GANIL integrates recent graphic enhanced processing units, namely VS3100-76 workstations and VT1300 X-terminals, to benefit from their color graphic high resolution capabilities and X-Window standard compliance. It is accomplished via operator consoles, supervision systems, and specific field graphic terminals.

Operator consoles

Operator consoles are installed in the main control room for centralized controls and along the accelerator for field controls and immediate interventions (e.g., the electronics backbone gallery and the experimental physics areas).

Two control levels:

1. Elementary level for individual equipment controls, the computer control system acting as a sophisticated multiplexer. This level provides utterly standardized controls for all pieces of equipment, by turning reassignable knobs,

2. Higher level for complex and global controls involving many different types of equipment, calculations and displays. This level achieves fully customized interactive controls, by running tasks.

Implementation:

Designation devices are currently trackball and mouse, to track and catch the graphic objects (task or knob image) on the screen of the X-Terminal.

Input device is keyboard to enter alphanum data, such as the name of a piece of equipment or an expected value.

Output device for control tasks is commonly the screen of the workstation for color graphics, associated with color print out devices.

Control devices are the popular reassignable knobs (shaft encoded potentiometers) which are used on the "one knob - one piece of equipment at a time control" basis. These shafts are grouped into four-unit module to achieve ergonomy and performances.

Pertinent alarm messages will be displayed on the console screens following a uniform presentation strategy with color coding to speed up interpretation. Operators can control specific actions from these consoles, such as activating the display of detailed DBMS messaging for inspection and diagnostics or acknowledging a specific or a whole class of alarms to clear the screens. Fig 4 shows an operator console unit.

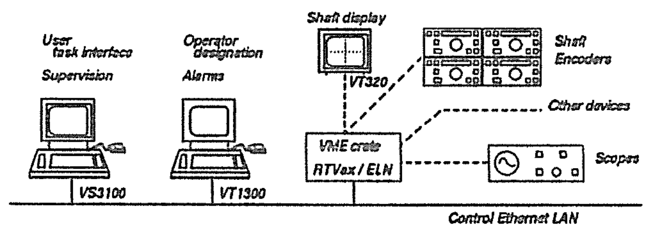

Figure 4. Operator Console Unit

Supervision

It uses worstations VS3100 to run the commercial software package IMAGIN supplied by SFERCA. This supervisory system allows control of any processor which is within the reach of the workstations, management and display of the collected data on animated synoptics over the background view. Supervised processors are currently programmable logic controllers (PLC) and the present control system. Imagin is composed of several software modules : a graphic editor, a configurer to create dynamic objects and an animator to perfom real-time display. Mailboxes provide communication threads between the animator module and the application process, as well as access synchronization to the shared data memory pool. PLC data acquisition is realized by the data server based on the SFERCA subsets PROLINK+ and its industrial database BDI (Fig 5).

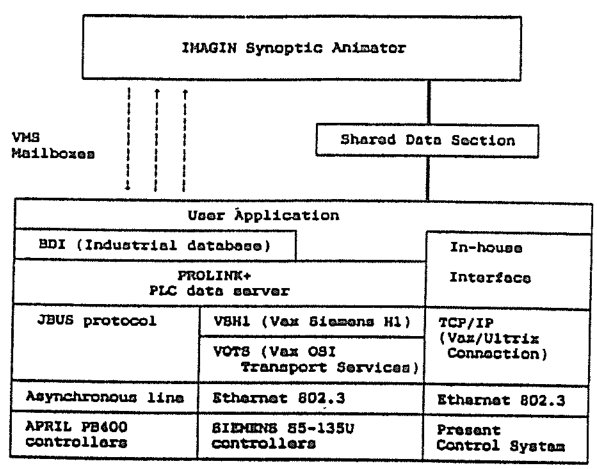

Figure 5. Supervision Structuration

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Supervisory development environment is organized around wokstations linked to the VAX 6000-410 host processor, while supervision is performed on workstations related to the µVAX3800 cluster. ADA and FORTRAN application processes are interfaced to the various SFERCA modules through specific interfaces. Recent implementations encompass DECwindows environment. Examples of supervision will be presented in the following section.

Field graphic terminals

Programmable logic controllers are addressable by dedicated field terminals with attached keyboards to perform specific actions. These devices are for use by specialists for local inspection and expertise.

III. First Implementations

III.1 Controls of the new ECR Ion source

A new 14.5 GHz ECR ion source, named ECR4, was installed on a 100 kV platforme to increase the beam intensity for metallic and heaviest ion species. This ECR source is controlled by a pair of SIEMENS S5-135U PLC. One PLC is on the high voltage platform and is linked by an optic fiber connection to its grounded companion. The grounded PLC is coupled to the Ethernet LAN to communicate with the supervision system running on a VS3100 workstation. An ADA application interfaces the IMAGIN software to animate synoptics. The ECR4 synoptics consists of several views to handle the RF power transmitter, to control the vacuum system and to drive the main parameters of the ECR source like the gas pressure of the UHF power, as shown on Fig 6.

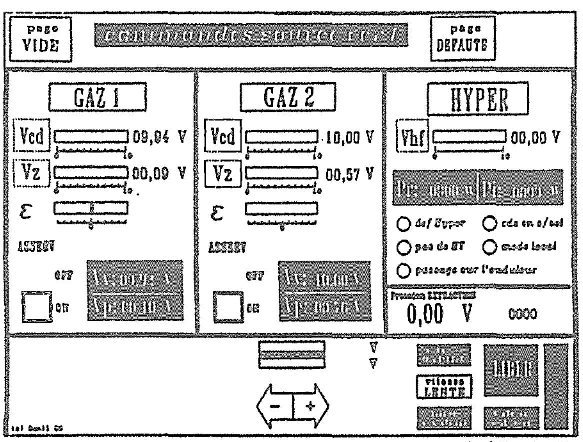

Figure 6. New ECR Ion Source Synoptic

III.2 Supervision of the internal temperature of the RF cavities

The temperature of water cooling the seven RF cavities of the accelerator are measured by the means of 34 PT100 probes connected to a SIEMENS S5-135U PLC and are supervised such as for the ECR source. In addition data related to beam characteristics, RF voltage and vacuum pressure are read from the present control system. Fig 7 shows the temperature measurements inside the northbound RF cavity of the first separated sector cyclotron (SSC1).

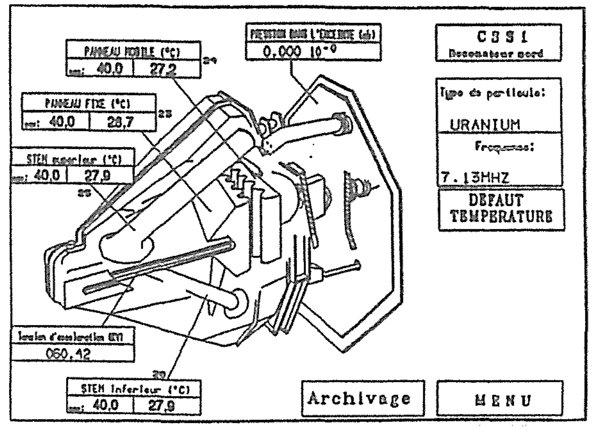

Figure 7. Temperature of a RF Cavity Synoptic

This application is the first experience of introducing relational database concepts into our controls environment. The INGRES RDBMS is used to archive measurements at operator request or in automatic mode, every 15 minutes. An off-line application using the Windows 4th Generation Language (W4GL) from INGRES displays graphs and presents result, depending on the stored data, as shown in Fig 8. It demonstrated the benefit that can be taken when developing with this language. It also led us to face the sensitive implementation of ADA/SQL interface and use of the ADA multitasking features in this case. The whole application is now about to be operational.

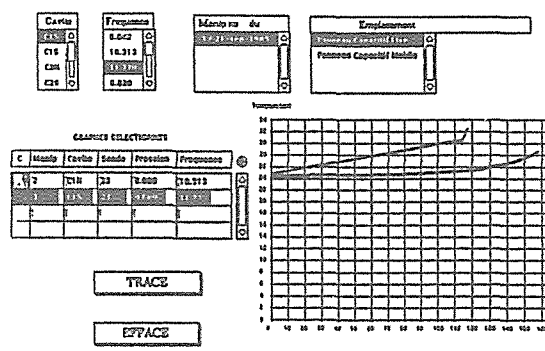

Figure 8. Off Line Display of a RF Cavity Temperature

III.3 Operation viewing and statistics

A W4GL application was written to store in an INGRES database the chronology of the GANIL operation. According to the screen displayed on Fig 8, the operator using a mouse has to point to or choose various graphic objects to specify what occurs while controlling the accelerator and the experimental areas. Every quarter of an hour, he has to indicate time and location of occuring failure, as well as beam tuning conditions and target experimental rooms. Later on, some of these manual operations will be filled up automatically.

The other part of this application to be developed will run on a Macintosh station. This application will read the INGRES database through the graphic query language (GQL) product to feed an EXCEL application for statics and report purpose. This application is planned to run by the beginning of the next year.

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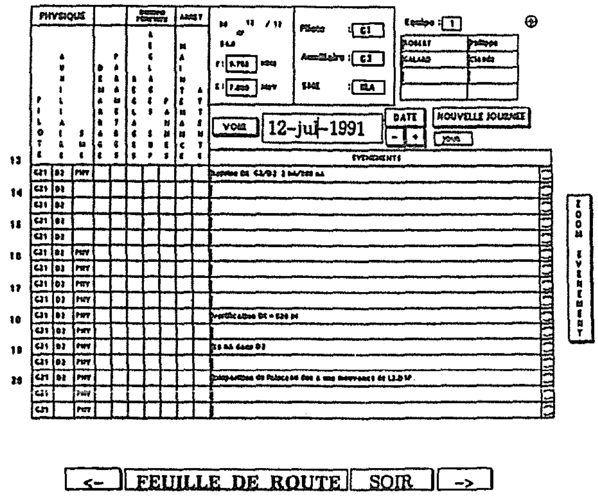

Figure 9. Operation Statistics Display

III.4 Beam profiler

It was important for us to validate by an example several real time control system basis components :

- Client server communication with workstations as clients and VME crates as servers.
- VME crates for the control of local pieces of equipment with data links to the control room workstation for display.
- The VME300 under VAXELN as crate controller.
- The DEC graphic editor VUIT to build MOTIF menus.

That was done with the beam profilers system in which the VME crate contains the 20 acquisition slots for 160 profilers.

On the VME crate, a communication server receives the requests from the workstations, according to the different allowed functions (gravity center, broken wires management, full width at half maximum). There is one ADA task for each function, so that simultaneous different requests can be satisfied. These functions find their data in an ADA task which is started by an interrupt at every end of the acquisition cycle.

After that, the computed data are sent by the LAN to the requesting workstation. An ADA program on this VMS workstation manages all the MOTIF widgets for the pop-up menus dedicated to the operator's choice, then displays and refreshes the graphic representation of eight beam profilers.

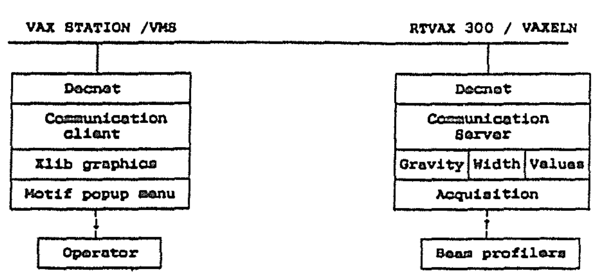

Figure 10. Beam Profiler Software Structuration

This beam profiler display application showed us that this kind of communication is fully satisfactory and can be extended to the fifteen other local control processes such as high frequency or beam phase management.

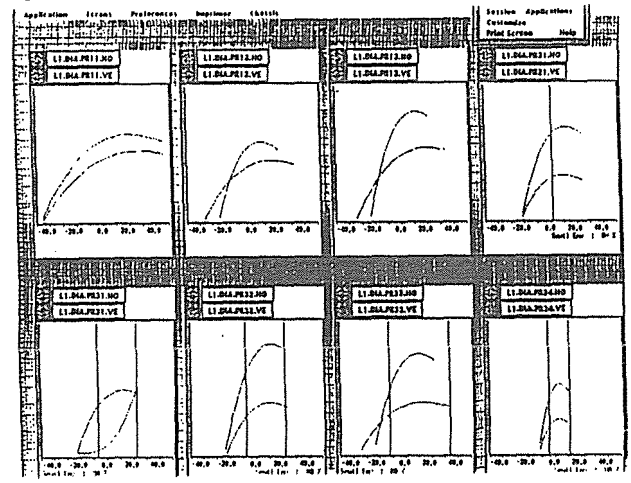

Figure 11. Beam Profiles

CONCLUSIONS

The host level is fully equipped and operating as well as the processors of the real-time control level : µVAX3800 cluster and workstations. The Ethernet LANs, to federate the three control levels are installed and provide satisfactory services.

Significant effort was deployed to analyze and build up the software architecture.

The next step will be mainly devoted to completing the GANICIEL specifications and to coding the system and user software.

The future control system is planned to run by spring 1993.

ACKNOWLEDGEMENTS

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We benefit from discussions we continue to have with the people from the Electronics Group and the Operation Group of the Accelerator Operation Sector.

FURTHER READINGS

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